AD NUMBER
AD907380
LIMITATION CHANGES
TO: **Approved for public release; distribution is unlimited.**
FROM: **Distribution authorized to DoD and DoD contractors only; Foreign Government Information; JUL 1972. Other requests shall be referred to British Embassy, 3100 Massachusetts Avenue, NW, Washington, DC 20008.**
AUTHORITY
DSTL, AVIA 37/1430, 8 Dec 2008

MINISTRY OF DEFENCE

EXPLOSIVES RESEARCH AND DEVELOPMENT ESTABLISHMENT

TECHNICAL REPORT No. 110

The Compatibility of Epoxy Resins with Explosives

N J Blay
E F Pembridge

FOR OVERSEAS RELEASE CONDITIONS SEE INSIDE COVER

WALTHAM ABBEY
ESSEX

July 1972

RELEASE CONDITIONS FOR OVERSEAS DISTRIBUTION

A

1. THIS INFORMATION IS RELEASED BY THE UK GOVERNMENT TO THE RECIPIENT GOVERNMENT FOR DEFENCE PURPOSES ONLY.
2. THIS INFORMATION MUST BE ACCORDED THE SAME DEGREE OF SECURITY PROTECTION AS THAT ACCORDED THERETO BY THE UK GOVERNMENT.
3. THIS INFORMATION MAY BE DISCLOSED ONLY WITHIN THE DEFENCE DEPARTMENTS OF THE RECIPIENT GOVERNMENT AND TO ITS DEFENCE CONTRACTORS WITHIN ITS OWN TERRITORY, EXCEPT AS OTHERWISE AUTHORISED BY THE DEFENCE RESEARCH INFORMATION CENTRE. SUCH RECIPIENTS SHALL BE REQUIRED TO ACCEPT THE INFORMATION ON THE SAME CONDITIONS AS THE RECIPIENT GOVERNMENT.
4. THIS INFORMATION MAY BE SUBJECT TO PRIVATELY-OWNED RIGHTS.

B

1. THIS INFORMATION IS RELEASED BY THE UK GOVERNMENT TO THE RECIPIENT GOVERNMENT FOR DEFENCE PURPOSES ONLY.
2. THIS INFORMATION MUST BE ACCORDED THE SAME DEGREE OF SECURITY PROTECTION AS THAT ACCORDED THERETO BY THE UK GOVERNMENT.
3. THIS INFORMATION MAY BE DISCLOSED ONLY WITHIN THE DEFENCE DEPARTMENTS OF THE RECIPIENT GOVERNMENT AND TO THOSE NOTED IN THE ATTACHED LIST, EXCEPT AS OTHERWISE AUTHORISED BY THE DEFENCE RESEARCH INFORMATION CENTRE. SUCH RECIPIENTS SHALL BE REQUIRED TO ACCEPT THE INFORMATION ON THE SAME CONDITIONS AS THE RECIPIENT GOVERNMENT.
4. THIS INFORMATION MAY BE SUBJECT TO PRIVATELY-OWNED RIGHTS.

C

1. THIS INFORMATION IS RELEASED BY THE UK GOVERNMENT TO THE RECIPIENT GOVERNMENT FOR DEFENCE PURPOSES ONLY.
2. THIS INFORMATION MUST BE ACCORDED THE SAME DEGREE OF SECURITY PROTECTION AS THAT ACCORDED THERETO BY THE UK GOVERNMENT.
3. THIS INFORMATION MAY BE DISCLOSED ONLY WITHIN THE DEFENCE DEPARTMENTS OF THE RECIPIENT GOVERNMENT, EXCEPT AS OTHERWISE AUTHORISED BY THE DEFENCE RESEARCH INFORMATION CENTRE.
4. THIS INFORMATION MAY BE SUBJECT TO PRIVATELY-OWNED RIGHTS.

D

5. THIS INFORMATION IS RELEASED FOR INFORMATION ONLY AND IS TO BE TREATED AS DISCLOSED IN CONFIDENCE. THE RECIPIENT GOVERNMENT SHALL USE ITS BEST ENDEAVOURS TO ENSURE THAT THIS INFORMATION IS NOT DEALT WITH IN ANY MANNER LIKELY TO PREJUDICE THE RIGHTS OF ANY OWNER THEREOF TO OBTAIN PATENT OR OTHER STATUTORY PROTECTION THEREFOR.
6. BEFORE ANY USE IS MADE OF THIS INFORMATION FOR THE PURPOSE OF MANUFACTURE, THE AUTHORISATION OF THE DEFENCE RESEARCH INFORMATION CENTRE. MUST BE OBTAINED.

MINISTRY OF DEFENCE

EXPLOSIVES RESEARCH AND DEVELOPMENT ESTABLISHMENT

Technical Report No 110

July 1972

The Compatibility of Epoxy Resins with Explosives

by

N J Blay
E F Pembridge

SUMMARY

The explosives compatibility properties of a number of commercial epoxy resin materials are discussed and reported and an account is given of hazard appraisal and compatibility tests of several reactive hardener components and of resin-hardener mixtures in the uncured condition.

Further copies of this technical report can be obtained from Defence Research Information Centre, Station Square House, St Mary Cray, Orpington, Kent. BR5 3RE

CONTENTS

Reference: WAC/220/08

1 INTRODUCTION

Most epoxy resin systems can be classified into two groups according to whether the cure proceeds satisfactorily at ambient temperatures or whether heating is required. In general cold-curing systems require the use of curing agents which are chemically more reactive than those used for hot curing. There are a few intermediate systems using rather less active hardeners and requiring longer ambient temperature cures but even with these, the full strength of the resin is not obtained without some heating.

When epoxy resins first became commercially available it was soon realised that the hardener components of the cold-curing varieties were usually severely incompatible with many important explosives. In several cases ignition of the explosive occurred within a few seconds of its being contaminated with the hardener and, in consequence, an almost complete ban was imposed in this country on the use of cold-curing epoxides in circumstances where any possibility of contact with explosives existed. More attention was given to the selection of suitable hot-curing systems and specifications were produced which made explosives-compatible grades of these materials available for use. However, the cure temperatures for these compounds are too high to be tolerated by most explosives and their use must, in general, be restricted to unfilled components.

The ban on cold-setting epoxides, because of incompatibility, has been a considerable handicap. Their properties are excellent in most other respects and in recent years the purchase of many types of foreign ammunition, later examined for possible incompatibilities between components, has brought to light several instances where cold-setting epoxides have been used. In some cases this has been because of ignorance of possible effects or lack of proper precautions to avoid the use of incompatible materials, but often the epoxides have been used in an apparently reasonable and safe manner. Also, a few cold-setting systems have emerged with better compatibility properties.

It has become clear therefore that there is a considerable advantage to be gained by a less rigid approach to the problem and it was the object of the work reported here to explore the limits within which cold-setting epoxides can be safely and advantageously used with explosives. At the same time, the opportunity has been taken to present some part of the information relating to compatibility tests made at ERDE with both hot- and cold-curing systems over past years.

2 NATURE OF INCOMPATIBILITY BETWEEN EPOXY RESINS AND THEIR COMPONENTS AND EXPLOSIVES

Most cold curing epoxy systems employ hardeners which are either fairly simple amines or contain reactive amine groups, and it is these compounds

which are responsible for most compatibility problems. Many amines react readily with organic nitrate esters including nitroglycerine and nitrocellulose. The reactions are complex but some indication of their nature can be obtained from the behaviour of model compounds such as ethyl nitrate and piperidine. In this case N-ethylpiperidinium nitrate is formed in fairly high yield but there are several other products as well.

Any material which reacts so readily with explosives is clearly incompatible, and this ease of reaction often extends to nitroaromatics and nitramines such as tetryl, TNT, RDX and HMX as well as compositions based on NG and NC. Also, the reactions are strongly exothermic and the heat which is produced may raise the temperature of the surrounding explosive mass to its ignition point. However it should be noted that there are many explosive compositions including most pyrotechnics and primary explosives and composite propellants to which these statements do not apply, and in these cases it is usually possible to use cold-setting epoxides with satisfactory results.

When assessing an epoxy resin system in regard to compatibility a number of other factors, besides the properties of the hardener, must be considered. For use, the hardener is greatly diluted by mixing with the epoxy resin, and the properties of this freshly-prepared mixture are of importance should contact between it and explosives occur either by intention or by accident before full cure is obtained.

The cured resin itself may be required to be in contact with explosives during long storage periods and its compatibility in this respect must be assessed and, when considering either the cured or uncured resins, some account should be taken of the consequences of incorrect formulation and in particular the use of an excessive quantity of hardener.

The uncured epoxy resins to which the hardeners are added are usually chemically compatible with explosives and residual incompatibility in the cured or partially cured material may be ascribed to a proportion of unreacted or partially reacted hardener. It is not unusual to find that the more reactive hardeners, those which are most incompatible with explosives, give cured resins of improved compatibility, presumably because of the completeness of their cure reaction.

3 MATERIALS TESTED

In most cases materials are identified by the manufacturer's code name. Further information is available from the firms' published data sheets. In general there are no Government specifications controlling the chemical compositions of these materials, although with some an element of control can be exercised by QAD (Mat) through existing Approved Firm's Schedules. This is always an important consideration for materials required to be compatible with explosives, since assurance is required that the formulation of the material tested will not be changed without notification to the Inspection Authority.

4 EXPERIMENTAL

4 1 Hazard Tests with Hardener Ingredients

A simple contact test has been used in this laboratory for many years to decide whether substances submitted for compatibility assessment are likely to cause a hazard during testing. 0.5 g of the material is mixed with 1 g of explosive or propellant and, if no obvious effect is produced within a few minutes, the mixture is heated on a water bath at 100°C for several hours.

This test was applied to the CIBA hardeners (Table 1) and in several cases ignition occurred at 100°C but not at room temperature. Ignition in this type of experiment largely depends upon whether the heat produced in the reaction is dissipated sufficiently to prevent self-heating of the mixture to its ignition temperature. In an attempt to increase the likelihood of ignition at normal temperatures, the tests in which this had occurred with the heated mixtures but not in the cold were repeated in close-fitting, expanded-polystyrene insulation jackets 1 inch thick (Table 2). This procedure was also used to study the effects of reducing the amounts of added hardener which were necessary to produce ignition of the explosives (Table 3).

The hardener/explosive combinations which had ignited at 100°C but not at room temperature were further examined by heating them at 5°C/min and noting the temperature of ignition (Table 4).

Further data on hardeners used by CIBA and other manufacturers are presented in Table 5. These results have been obtained in the course of a number of compatibility investigations and most of the materials have not been tested in as much detail as the CIBA hardeners listed in Tables 1 to 4.

4 2 Tests of Uncured Resin/Hardener Mixtures

The properties of freshly-prepared, resin-hardener mixtures were examined by similar contact tests using the polystyrene jackets. The mixtures were prepared both in the recommended proportions and also with twice the required amount of hardener. Tests were made with a double-base propellant and with CE at ambient temperature for 24 hours against mixtures containing those hardeners which had previously caused ignition. The results in Table 6 record an ignition in only one case, but nearly all the mixtures showed evident signs of reaction with CE by reason of the deep red coloration which was produced. The only hardener to appear entirely satisfactory in these tests was HT 972, and with one or two other exceptions where the hardeners are compatible even before mixing, the uncured mixtures are not suitable materials to be placed in contact with explosives.

4 3 Tests of Cured Resins

Table 7 contains the results obtained from the tests of cured Araldite systems following the standard procedures usually applied in compatibility

tests at ERDE a general account of which is given in the Appendix. In the present case the Silvered Vessel test for propellants and the Vacuum Stability test for high explosives were applied. Table 8 lists the results obtained during past tests of a number of other cured epoxy resins.

5 RESULTS

5 1 Double-Base Propellants

As has been observed with many previous tests, the Silvered Vessel compatibility results in Table 7 are higher than the control test levels, with the epoxy resin appearing to act as a propellant stabiliser. This is not surprising in view of the structure of these materials, made from aromatic epoxides which can be fairly readily nitrated. However, there are other aspects of their compatibility with propellants which are less satisfactory. It has already been mentioned that the room-temperature, amine-cured systems are almost always left with traces of unreacted hardeners and the effects of these can often be easily detected by other methods of compatibility testing. In many cases, propellants kept in contact with cured epoxy resins of this type in accelerated ageing tests will be found to lose their stabiliser content at an excessive rate and to produce greater volumes of gas and greater quantities of heat. The extent of this accelerated decomposition varies with the resin system and under the Silvered Vessel test conditions it usually peters out without producing enough self-heating to cause fume-off. The resin material, after the reaction of the residual active hardener, can then supplement the action of the propellant stabiliser to give an increased test time.

Therefore, although the Silvered Vessel test gives a considerable degree of assurance in regard to the safety of the cured resins in contact with double-base propellants, their acceptance should also be judged in relation to the possible effects that the increased heat evolution, gassing and chemical deterioration of the propellant may have.

Conclusions reached from stabiliser consumption and other trials where available are included in Table 8, and there are comparatively few systems which give no sign of incompatibility by these methods although this is often within acceptable limits.

5 2 High Explosives

The Vacuum Stability compatibility test is a direct indication of reaction with the explosive and the results are perhaps easier to interpret. In most cases the acceptance limit is set at a gas evolution of 5 cm^3 from 5 g of explosive in the test. This gas is not produced by the complete breakdown of a minute part of the explosive to entirely gaseous products but by decomposition of a larger proportion to a mostly non-volatile residue and possibly only one or two moles of gas. The upper acceptance limit thus corresponds to an extent of decomposition which is in the order of 1% for the usual high explosives.

Experience has shown that a large majority of synthetic materials pass this test and there is no reason to suppose that to base judgements upon it is unduly restrictive. Nevertheless, substances which pass the test would, if this were required of them, be considered as suitable additives for mixing as ingredients in the explosive. To require the same standard from a material which is to be used in only surface contact perhaps over a small area, or merely in close proximity to the explosive may be considered excessively cautious. This argument is strongest in the case of RDX/TNT and related explosives where for many years it has been customary to use a test temperature of 120°C. It is of interest to contrast the results obtained with CE tested at 100°C and RDX/TNT or Torpex tested at 120°C as shown in Tables 7 and 8. It is immediately obvious that the volumes of gas produced by RDX/TNT and Torpex are in the great majority of cases much higher than are produced by CE. Many of the resins are therefore judged as incompatible with one explosive but compatible with the other although, as can be seen in the 100°C results for RDX/TNT in Table 7, this is principally because the test temperatures are different. Since the service life requirements for the two explosives as part of the same warhead are almost certain to be the same there appears to be no valid reason for this. The test at 100°C for 40 h is in any case a severe one which some other explosive components, eg propellants, would not be expected to pass and which, applying the usual temperature factors to explosive decomposition is a considerable over-test in terms of normal service life requirements. Also, since explosives containing TNT cannot be used above about 75°C because of melting, it seems inappropriate to require better compatibility for them at high temperatures than for CE. There is thus a strong argument for changing the present procedure to introduce a common temperature of 100°C for compatibility testing with all high explosives based on RDX, HMX, TNT, PETN, ammonium nitrate and CE unless there is a specific requirement for high temperature stability.

A further important consideration, particularly with TNT explosives, is the absence of excessive alkalinity or acidity. The amine type hardeners sometimes leave the cured resins with a perceptibly alkaline reaction which is undesirable. These aspects are taken into account in Table 8 in which the compatibility judgements for the various resin systems are given.

5 3 Other Explosives

This report has been principally concerned with compatibility with nitrocellulose-based propellants and the usual military high explosives but it would not be complete without an indication of properties in relation to the large number of other explosives which are in use.

5 3 1 Composite Propellants Including Plastic Propellants

No instance of incompatibility with cured or uncured epoxy resins has been reported with composite propellants, consisting essentially of ammonium perchlorate and a polymeric binder, or with plastic propellants typified by RD 2304 and containing ammonium picrate. A reservation must however be made in the case of systems with high residual alkalinity.

5 3 2 Other High Explosives

This group includes amatols, minols, Torpexes, pentolite, baratol, RDX/Wax, RDX/Nylon, and other RDX- and HMX-based explosives. In general their behaviour tends to resemble RDX/TNT or CE and the results for these explosives can be taken as an indication of the likely effect of the epoxy resins. Supplementary results covering some combinations are given in Table 8.

5 3 3 Initiatory Explosives

Direct contact between most of the common initiatory explosives and epoxy resins or their components does not appear to introduce a serious risk of chemical reaction leading to explosion.

For example, neither the reactive amine hardeners such as Araldite HY 951 and HY 956 nor uncured epoxy resins have any immediately dangerous effect on initiators such as lead azide, LDNR or lead or barium styphnate although some obvious reaction paths exist such as the formation of volatile azides.

Similarly with cured resins, no instances of direct chemical incompatibility can be cited although, as always with initiatories, the possible effects on physical sensitiveness must also be considered.

Some adverse effects should however be mentioned. Absorption of an uncured or partially cured liquid resin by an initiator explosive would be expected to cause a great reduction in sensitiveness and this combination of materials is therefore not advisable. More serious is the incompatibility observed when small specimens of lead azide are exposed in proximity to relatively large amounts of epoxy resins. Considerable decomposition of the azide occurs in these circumstances and all epoxy resins are therefore included among the large number of synthetic materials which, because of similar effects, have been judged as unsuitable for use in fuzes and other assemblies containing unsealed lead azide detonators. Lead azide is especially susceptible to this type of incompatibility but the possibility of such effects must be borne in mind whenever it is proposed to expose small increments of any explosive over long periods to the vapours emitted from very much larger quantities of synthetic materials, particularly in sealed systems. However, no other proven examples applying to epoxy resins can be cited at present.

5 3 4 Pyrotechnics and Gunpowder

No instances of chemical incompatibility which could lead to a hazard have been reported and epoxy resins have been used with many pyrotechnic compositions as adhesives, moulded components and in some cases as binder ingredients for the explosives.

The large number of pyrotechnics makes it impossible to reach a general conclusion that there can be no incompatibilities with epoxy resins but certainly these are uncommon. Gunpowder has also been tested with many epoxy systems but no adverse effects have been noted. However, the same reservations as were made about initiators also apply to pyrotechnics. Liquid,

uncured resins applied to these compositions, would be absorbed with consequent effects on performance, and vapours from plastics, including epoxy resins, might conceivably cause deterioration of small pyrotechnic devices such as delay sleeves under unfavourable circumstances. This possibility is known to exist but no case involving an epoxy resin has been found.

6 CONCLUSIONS

6 1 The compatibility properties of epoxy resins and their ingredients with explosives vary considerably and there will be notable exceptions to any general statements of properties such as appear in these conclusions. This should be appreciated and no assumptions should be made regarding the compatibility of these materials, until appropriate tests are known to have been made with the resin in question.

6 2 The uncured epoxide resin components of most commercially-available, epoxide systems are, as a rule, chemically compatible with most explosives.

6 3 The hardener components of those epoxy resins which can be cured at ambient temperatures or with moderate heat are frequently dangerously incompatible with colloidal propellants and high explosives (Tables 1 to 5). Hardeners known to be in this class include:

CIBA	Shell	Borden	Others
HY951	K61A	M715	Versamid 115
HY956	K61B	EHL5	Versamid 125
HY960		EHL7Z	Piperidine
HY992			Triethylenetetramine
HV100			N-aminoethyl piperazine
HY219			
HY953F			

6 4 A few hardeners for cold- or warm-setting systems are judged to be safe for use with explosives. These include:

CIBA	Borden
HY830 (and Accelerator DY830)	EHR1
HY850	EHM4

6 5 Newly-prepared and uncured mixtures of resins and hardeners in the recommended proportions do not as a rule cause ignition of propellants or explosives in laboratory tests (Table 6). In nearly all cases this is still true when twice the recommended proportion of hardener is added and such mixtures are much less hazardous than the hardeners themselves.

6 6 Many cold- or warm-setting epoxy resins when fully cured are compatible with at least some propellants and high explosives (Tables 7 and 8). When incompatibility is observed, it is rarely extreme enough to cause an immediate hazard, although long-term effects are less certain.

6 7 The problem of incompatibility with cold-curing epoxides is, in general, restricted to colloidal propellants and high explosives. No case of extreme and hazardous incompatibility has arisen with primary explosives, gunpowder, pyrotechnics or composite propellants, although some adverse effects are possible.

6 8 Hot-cured epoxides with anhydride-type hardeners are usually compatible or, at worst, only moderately incompatible with explosives. Some materials of this type have been supplied for several years in explosives-compatible grades to "Type X" specifications.

APPENDIX

METHODS OF COMPATIBILITY TESTING

1 PROCEDURES FOR PROPELLANTS (SINGLE-, DOUBLE- AND TRIPLE-BASE)

1 1 Silvered Vessel Test

This test measures the time taken by a propellant, heated at 80°C, to reach a stage of decomposition in which fuming and self-heating become evident. By careful standardisation of the conditions, reproducible results are obtained and the effect of contaminating the propellant with a 5% addition of the material under examination for compatibility can be measured.

The test material is ground or rasped into small fragments and mixed with ground propellant in the proportion 1:20. The mixture is filled into a "Silvered Vessel", which is a spherical, silvered, vacuum-jacketed flask of about 90 cm^3 capacity with a long horizontal side-arm joined to its narrow neck. The flask, when full contains 70 g of propellant/sample mixture which has to be compressed quite firmly. The neck of the flask is closed by a cork which carries a thermometer whose bulb rests at the centre of the spherical part of the flask.

The flask is heated in a special bath and observed for either increase in temperature or the commencement of the evolution of brown fumes which appear in the long side arm. By looking down the side-arm and arranging a white screen behind the flask, the fuming can be easily seen. The first signs of fuming are, in most instances, quickly followed by an increase in temperature. The test is terminated when the temperature rises to 82°C, and this usually occurs between 12 and 24 hours after commencement of fuming. The test time is compared with that obtained from the propellant tested alone in a similar manner.

Most Service propellants have a time to fuming in the test which is inconveniently long and a special propellant type composition, designated F527/327 with the following composition is therefore used.

Nitrocellulose (13.2% N)	37)	
	)	93.5%
Nitroglycerine	58)	
Dibutyl Phthalate	6%	
2-Nitrodiphenylamine	0.5%	

The decomposition of this composition is observed after about 650 hours at 80°C and the limit of acceptability in compatibility tests is at 66% of the observed result for the propellant alone.

APPENDIX

1 2 Stabiliser Consumption Tests

Mixtures of propellant and test material (20:1) are heated in closed glass tubes. The mixture is analysed for residual stabiliser at the end of the test, and the loss of stabiliser in the test is compared with that occurring with the propellant heated alone under similar conditions. The usual weight of propellant taken is 5 g, and the temperature and time of heating are chosen so that the propellant, when heated alone, loses a measurable, but not excessive amount of stabiliser. For most double-base gun propellants this requires 2 to 4 weeks heating at 80°C, but with propellants of lower stabiliser content, lower temperatures can sometimes be used.

Materials are judged to be satisfactorily compatible if they cause less than a 33⅓% increase in the amount of stabiliser lost by the propellant.

2 PROCEDURE FOR HIGH EXPLOSIVES

Vacuum Stability Test

Most compatibility testing with high explosives is carried out by means of the Vacuum Stability test, the procedure for which is similar to that given in QAD(Mats) Method EB26. For compatibility tests, a mixture of 5 g of explosive and 0.25 g of test material is prepared and the gas evolved during a 40 hour heating period is measured. The test temperature is 100°C for the following explosives, tetryl, amatol, PETN (pentaerythritol tetranitrate), and 120°C for TNT, RDX, HMX, RDX/TNT and similar compositions. The test temperatures were chosen so that the explosive when heated alone should give a detectable volume of gas in the test.

After making allowance for the gas evolved by the explosive and material when heated separately in control tests the acceptance limit for gas evolution from the mixture is 5 cm^3 at STP in the 40 hour test period.

Note: The shortened method of calculation given in Method EB26 is not used.

3 PROCEDURE FOR PYROTECHNICS AND INITIATORS

The methods of test for compatibility with these explosives have not been standardised, but often consist of storage tests lasting from 1 to 12 weeks, at temperatures up to 80°C, of mixtures of explosive and test material, followed by chemical analysis of the explosive and tests for possible degradation products.

The chemical reactivity of many of these explosives is greatly influenced by the presence of water and the storage experiments frequently include tests conducted under humid conditions.

APPENDIX

Where the explosive is to be used in very small amounts, as is usually the case with initiators, attention is also given to the possible effects which may result from being enclosed in an environment containing relatively large amounts of other materials. These materials are tested by enclosing large quantities (10 to 20 g) in a sealed container together with a much smaller amount of the explosive. After storage at 60 or 80°C often under humid conditions, the explosive is analysed to detect excessive deterioration.

4 PROCEDURE FOR GUNPOWDER

Small Vessel Test

Most compatibility testing with gunpowders is carried out by means of the Small Vessel test, the procedure for which is given in QAD(Mats)Method EA20.

For compatibility tests a mixture of 2 g of gunpowder with 0.1 g of test material is prepared and the loss in weight of 6 × 24 hour heating periods at 100°C is recorded. The degree of breakdown is indicated by the loss in weight. After making allowance for the loss in weight of the gunpowder and material when heated separately in control tests, the acceptance limit for weight loss from the mixture is excess of 1% of its original weight during one period of heating. The loss in weight during the first period includes the volatile matter content of the gunpowder and this must be taken into account when considering whether excessive decomposition has occurred.

5 OTHER TESTS

Most materials tested for compatibility are also tested for excessive acidity and alkalinity. This is done by examining the water extract prepared from 1 part by weight of material to 10 parts of water. The pH value of the extract is read using a glass electrode and calomel electrode assembly. Values between 5 and 9 are regarded as satisfactory for materials used in contact with explosives.

Thermo-analytical methods are also used for assessing compatibility but procedures are not standardised. Differential Thermal Analysis and Differential Scanning Calorimetry give useful information, particularly when compatibility at high temperatures is in question.

Thermogravimetric analysis is also used in certain instances, more particularly with pyrotechnics. Heating programmes in these types of test frequently include periods of isothermal heating. The application of the vacuum stability test to testing for compatibility with high explosives has been described. It is also occasionally used for tests with propellants and

pyrotechnics, particularly those containing magnesium powder. In this latter instance the test measures the reactivity of moisture in the material with magnesium. The temperature of these tests is usually lower (60 or 80°C) and the test time longer (up to 14 days) than in tests with high explosives.

TABLE 1

ARALDITE HARDENERS (CIBA(ARL) LTD)
TIME TO IGNITION WITH EXPLOSIVES (IN SECONDS) (EXPLOSIVE/HARDENER 1 g/0.5 g)

Hardener	F527/327 Propellant		CE Grade I Crystn		RDX/TNT 60/40		Plastic Propellant RD 2304		Gunpowder G20	
	Room Temp	Boiling Water Bath	Room Temp	Boiling Water Bath	Room Temp	Boiling Water Bath	Room Temp	Boiling Water Bath	Room Temp	Boiling Water Bath
HY 951	13		27		A Red colour	14	A	A	A	A
HY 956	75		A Red colour	19	A Red colour	23	A	A	A	A
Accelerator DY 830	A	A	A	A	A	A	A	A	A	A
HY 960	A	8	A Red colour	38	A Red colour	160	A	A	A	A
HV 100	A	225	A Red colour	A Red colour	A Red colour	A Red colour	A	A	A	A
HT 972	A	A	A	A	A Red colour	A Red colour	A	A	A	A
HY 992	6		20		90		A	A	A	A
*HY 830	A	A	A	A	A	A	A	A	A	A
*HY 850	A	A	A	A	A	A	A	A	A	A
HY 219	A	A Bubbling, Charred	A Red colour	A Red colour	A Red colour	A Red colour	A	A	A	A
Polyamide 115	A	165	A Red colour	A Red colour	A Red colour	A Red colour	A	A	A	A
Polyamide 125	A	105	A Red colour	A Red colour	A Red colour	A Red colour	A	A	A	A
N-aminoethyl piperazine	10		40		A Red colour	8	A	A	A	A

A - No ignition in 24 hours
* - Compatible with F527/327 propellant by SV test

TABLE 2

CONTACT TRIALS AT ROOM TEMPERATURE UNDER INSULATED CONDITIONS
TIME TO IGNITION (IN SECONDS) (EXPLOSIVE/HARDENER 1 g/0.5 g)

Hardener	F527/327 Propellant	CE Grade I Crystn	RDX/TNT 60/40
HY 951	10 9	25 27	A
HY 956	38 44	A	A
Accelerator DY 830	A	A	A
HY 960	325 314	A	A
HV 100	A	A	A
HT 972	A	A	A
HY 992	7 5	23 20	29 27
HY 830	A	A	A
HY 850	A	A	A
HY 219	A	A	A
Polyamide 115	A	A	A
Polyamide 125	A	A	A
N-aminoethyl piperazine	6 6	36 40	A

A - No ignition in 24 hours

TABLE 3

CONTACT TRIALS AT ROOM TEMPERATURE UNDER INSULATED CONDITIONS
TIME TO IGNITION (IN SECONDS)

Hardener	Proportion of Explosive/Hardener (by weight)	F527/327 Propellant	CE Grade I Crystn	RDX/TNT 60/40
HY 951	4/1	10	27	
	8/1	10	27	
	24/1	10	30	
HY 992	4/1	8	20	26
	5/1		20	
	6/1		18	
	8/1	8	18	35
	12/1		20	A
	24/1	8	22	A
HY 956	4/1	54		
	8/1	53		
	12/1	57		
	24/1	A		
HY 960	4/1	372		
	8/1	A		
N-aminoethyl piperazine	4/1	10	30	
	5/1		30	
	6/1		28	
	8/1	10	28	
	12/1		44	
	24/1	11	A	

A - No ignition in 24 hours

TABLE 4

TEMPERATURE OF IGNITION TESTS
(EXPLOSIVE/HARDENER 1 g/0.5 g)

Hardener	F527/327 Propellant	CE Grade I Crystn	RDX/TNT 60/40
HY 951			60°C
HY 956		65°C	70°C
HY 960	60°C	90°C	100°C (Ignited 105 seconds after being held at 100°C)
HV 100	100°C (Ignited 88 seconds after being held at 100°C)		
Polyamide 125	90°C		
Polyamide 115	100°C (Ignited 29 seconds after being held at 100°C)		
N-aminoethyl piperazine			60°C

TABLE 5

MISCELLANEOUS HARDENERS
TIME TO IGNITION WITH EXPLOSIVES (IN SECONDS) (EXPLOSIVE/HARDENER 1 g/0.5 g)

Hardener	F527/327 Propellant		CE Gde I Crystn		RDX/TNT 60/40		Plastic Propellant RD 2304		Gunpowder G20	
	Room Temp	Boiling Water Bath	Room Temp	Boiling Water Bath	Room Temp	Boiling Water Bath	Room Temp	Boiling Water Bath	Room Temp	Boiling Water Bath
Epophen Hardener (Borden) M 715	70		A Red Colour	3	A Red Colour	1800	A	A	A	A
Epophen Hardener EHL-5	A	5	A Red Colour	118	A	210				
Epophen Hardener EHL-7Z	A	A Charred	A Red Colour	A Red Colour					A	A
Epophen Hardener EHM-2					A	A				
Piperidine	2		A Red Colour	15	A Red Colour	5	A	A	A	A
Epophen Hardener EHR-1	A	AA	A	A(B)	A	A(B)	A	AA	A	A
Epophen Hardener EHM-4	A	A	A	A	A	A	A	A	A	A
Versamid 115	A	165	A Red Colour	A Red Colour	A Red Colour	A Red Colour				
Versamid 125	A	105	A Red Colour	A Red Colour	A Red Colour	A Red Colour				
Hardener (Shell Chemicals Ltd) K61A	A	93	A Red Colour	A Red Colour	A Red Colour	A Red Colour				
Hardener (Shell Chemicals Ltd) K61B	A	115	A Red Colour	A Red Colour	A Red Colour	A Red Colour				
HY 953F (CIBA)	A Evident Reaction	190	A Brown Colour	A Charred	A Red Colour	A Charred				

A - No ignition in 24 hours

AA - Passes SV or VS Test

A(B) - No ignition but does not pass VS test

TABLE 6

CONTACT TRIALS AT ROOM TEMPERATURE WITH FRESHLY MIXED RESIN-HARDENER SYSTEMS

Resin	Hardener (Proportion pbw per 100 of resin)	Notes
MY 750	HY 951 (12)	A C
MY 750	HY 951 (24)	A C
MY 750	HY 956 (25)	A C
MY 750	HY 956 (50)	A C
MY 750	HY 960 (12)	A D
MY 750	HY 960 (24)	A D
MY 750	HT 972 (27)	A E
MY 750	HY 992 (11)	A C
MY 750	HY 992 (22)	A C
MY 750	HY 951 (6), HY 992 (5)	A C
MY 750	HY 951 (12), HY 992 (10)	A C
MY 750	HY 956 (12.5), HY 992 (5)	A C
MY 750	HY 956 (25), HY 992 (10)	A C
AY 103	HY 951 (10)	A C
AY 103	HY 951 (20)	A C
AY 103	HY 956 (18)	A C
AY 103	HY 956 (36)	A C
AY 105	HY 951 (12)	A C
AY 105	HY 951 (24)	A C
AY 105	HY 956 (24)	A C
AY 105	HY 956 (48)	A C
AY 105	HT 972 (27)	A E
AY 105	NAEP (23)	A C
AY 105	NAEP (46)	B -
AY 121	HY 951 (4.5)	A C
AY 121	HY 951 (9)	A C
AY 121	HY 956 (10)	A C
AY 121	HY 956 (20)	A C
AV 100	HV 100 (100)	A D

NOTES

A - No ignition with CE or propellant F527/37 within 24 hours
B - Ignited propellant F527/327 in 96 seconds and CE in 214 seconds
C - Deep red colour produced with CE
D - Red or pink colour with CE
E - No colour with CE

TABLE 7

TESTS OF CURED RESINS

Resin Tested[1] and Conditions of Cure				Silvered Vessel Tests[2] (80°C)		Vacuum Stability Tests[3] [4]			Initiators
				Hours to Fuming	Hours to 2°C Rise	CE Grade I Crystn (cm^3/5 g, 40 h at 100°C)	RDX/TNT 60/40[5] cm^3/5 g, 40 h at 100°C	RDX/TNT 60/40[5] cm^3/5 g, 40 h at 120°C	
Control (Explosive only)				623	632	0.34	0.41	0.90	
MY 750/HY 951	100/12	24 h	at 20°C	1343	1469	0.00	5.14	10 h	Lead Styphnate) LDNR)[C]
MY 750/HY 956	100/25	24 h	at 20°C	1343	1503	1.72	5.27	2 h	
MY 750/HT 972	100/27	5 h	at 100°C	1259	1298	0.30	0.31	2.91	
MY 750/HY 960	100/12	12 h	at 40°C	1671	1710	0.28	9.82	1 h	
MY 750/HY 992	100/11	14 h	at 60°C	1812	1865	0.19	0.48	3.87	
MY 750/HY 951/HY 992	100/6/5	3 days	at 20°C	1343	1517	2.72	3.16	10 h	
AY 103/HY 951	100/10	24 h	at 20°C	1524	1545	1.66	1.70	24 h	
AY 103/HY 956	100/18	24 h	at 20°C	1623	1702	3.27	2.46	10 h	
AY 105/HY 951	100/12	12 h	at 40°C	1311	1332	1.04	0.99	22 h	
AY 105/HY 956	100/24	12 h	at 40°C	1261	1285	1.13	1.34	20 h	
AY 105/HT 972	100/27	2 h	at 80°C	1167	1194	0.23	0.31	4.08	
AY 121/HY 951	100/4.5	24 h	at 20°C	1257	1275	2.87	3.39	17 h	
AY 121/HY 956	100/10	24 h	at 20°C	1464	1504	3.14	6.56	11 h	
AV 100/HV 100	100/100	24 h	at 20°C	1812	1851	1.24	3.23	13 h	Lead Styphnate) LDNR)[C]

(1) All resin/hardener mixes are parts by weight

(2) Tests carried out using 70 g ground propellant (F527/327) with 5% cured cement, ground to powder before mixing with the propellant.
(F527/327 propellant: NC/NG 37/58 93.5; DBP 6.0; 2-NDPA 0.5)

(3) Tests carried out using 5 g explosive with 5% cured cement

(4) Volumes of gas evolved from resin/hardeners alone were NIL

(5) In the results for tests with RDX/TNT at 120°C, where times are quoted instead of volumes, the capacity of the apparatus (ca 15 ml) was exceeded in these times.

C = compatible

TABLE 8

PREVIOUS TESTS OF CURED RESINS

No	Resin Ingredients and Cure Schedule	Manufacturer	pH Value (aqueous extract)	Compatibilities (C = Compatible; I = Incompatible)							Clearance with Pyrotechnics, Initiators and Plastic Propellants
				High Explosives (VS Results)				Colloidal Propellants			
									Stabiliser Tests		
				CE at 100°C	RDX/TNT at 120°C	TORPEX 4A at 120°C	Others	SV Test at 80°C	Propellant and Stab Content	Trial Conditions	Increase in Stabiliser Consumption	
1	MY 750/HY 905B 100/100 pbw 3 h at 180°C	CIBA (ARL) Ltd	6.1	C (0.00 ml)	C (2.50 ml)	C (1.24 ml)	Amatol (C) (0.38 ml) Pentolite (C) (2.50 ml)	C (939 h)	SC 8.81 (Carbamite)	4 weeks 80°C Cured Resin	16% (C)	Plastic Prop RD2304 (C) (0.43 ml)
2	MY 750/HY 964B/ACC 964C 100/130/1 pbw 8 h at 100°C	"	3.9	C (1.37 ml)	C (4.29 ml)		Amatol (I) (9.78 ml)	C (2336 h)	"	"	31% (I)	
3	MY 750/HT 972 100/27 pbw 20 h at 100°C	"	7.6	C (0.30 ml)	C (2.91 ml)	C (4.35 ml)	Amatol (C) (4.37 ml)	C (1259 h)	"	"	5% (C)	
4	MY 750/MY 905/DY 061 100/100/1 pbw 1½ h at 120°C	"	6.6	C (0.11 ml)	C (2.30 ml)	C (2.41 ml)						
5	MY 750/VERSAMID 115 50/50 pbw	"										
	(1) 24 h at room temp		8.0	C (2.62 ml)		I (12.99 ml)			SC	4 weeks 80°C	50% (I)	
	(2) 20 min at 150°C		8.6	C (1.79 ml)		C (3.54 ml)			8.81 (Carb)	Resin cured 20 min 150°C		
6	MY 750/HY 219/DY 219 100/50/10 pbw 24 h at room temp	"	5.1	C (4.58 ml)		I (12.70 ml)	Amatol (I) (13.63 ml)	C (2512 h)	SC 8.81 (Carb)	4 weeks 80°C Cured Resin	12% (C)	
7	MY 750/HY 905/DY 064 100/100/1 pbw 8 h at 100°C	"	4.6	C (0.01 ml)		C (2.50 ml)	Amatol (C) (2.79 ml)	C (880 h)	"	"	11% (C)	
8	MY 750/HT 976 100/30 pbw 6 h at 180°C	"	7.4	C (0.30 ml)		C (2.90 ml)	RDX (C) (0.20 ml) Pentolite (C) (3.35 ml) TNT (C) (0.29 ml)	C (2118 h)	"	"	8% (C)	

TABLE 8 (Contd)

No	Resin Ingredients and Cure Schedule	Manufacturer	pH Value (aqueous extract)	Compatibilities (C = Compatible; I = Incompatible)							Clearance with Pyrotechnics, Initiators and Plastic Propellants
				High Explosives (VS Results)				Colloidal Propellants			
									Stabiliser Tests		
				CE at 100°C	RDX/TNT at 120°C	TORPEX 4A at 120°C	Others	SV Test at 80°C	Propellant and Stab Content	Trial Conditions	Increase in Stabiliser Consumption	
9	MY 750/HY 964/DY 064 100/130/1 pbw 8 h at 100°C	CIBA (ARL) Ltd	3.9	C (1.14 ml)	C (4.21 ml)	C (3.92 ml)	Amatol (I) (10.41 ml)	C (979 h)	SC 8.81 (Carbamite)	4 weeks 80°C Cured Resin	14% (C)	
10	Aero Research Adhesive 2800 (MY 750/HY 905B/Sb_2O_3 60/60/40 pbw) 3 h at 180°C	"	4.7	C (0.20 ml)	C (3.71 ml)	C (1.40 ml)	Amatol (C) (0.50 ml) Pentolite (C) (2.80 ml)	I (505 h)	"	"	3% (C)	Plastic Prop RD2304 (C) (0.45 ml)
11	MY 753/HT 972 100/22 pbw	"										
	(1) Uncured		6.3	C (4.27 ml)		I (10.27 ml)		C (3366 h)	"	4 weeks 80°C Uncured Resin	29% (I)	
	(2) 1½ h at 145°C		6.5	C (0.21 ml)		C (2.95 ml)		C (2584 h)	"	Cured Resin	12% (C)	
	(3) 7 days at room temp		6.5	C (0.71 ml)		C (3.11 ml)	Amatol (I) (12.10 ml)	C (2617 h)	"	Cured Resin	13% (C)	
12	MY 753/VERSAMID 115 50/50 pbw	"										
	(1) 24 h at room temp		8.7	C (1.96 ml)		I (11.11 ml)			"	4 weeks 80°C	36% (I)	
	(2) 20 min at 150°C		9.4	C (3.45 ml)		C (6.60 ml)			"	Cured Resin 20 min 150°C		
13	MY 753/HY 972/DY 219 100/22/5 pbw 24 h at room temp	"	5.6	I (6.38 ml)		I (8.75 ml)	Amatol (I) (10.12 ml)	C (2512 h)	"	4 weeks 80°C Cured Resin	10% (C)	
14	MY 753/HY 951 100/10 pbw 24 h at room temp	"	9.2	I (6.78 ml)		I (10.65 ml)	Amatol (I) (15 ml) Pentolite (I) (11.31 ml)	C (3148 h)	"	"	36% (I)	Plastic Prop RD2304 (C) (1.20 ml) Gunpowder G20 (C) Composition SR371C (C) Lead Styphnate (C) Lead Dinitroresorcinate (C)
15	Aero Research Adhesive 2700 (MY 753/HY 903/MEKX) 1 min at 175°C plus 1 h at 140°C plus 2 h at 180°C	"	5.7	C (0.00 ml)	C (3.11 ml)	C (1.34 ml)	Amatol (C) (1.89 ml) PETN (C) (0.16 ml)	C (2824)	"	"	4% (C)	Plastic Prop RD2304 (C) (1.58 ml)

TABLE 8 (Contd)

No	Resin Ingredients and Cure Schedule	Manufacturer	pH Value (aqueous extract)	Compatibilities (C = Compatible; I = Incompatible)								Clearance with Pyrotechnics, Initiators and Plastic Propellants
				High Explosives (VS Results)				Colloidal Propellants				
									Stabiliser Tests			
				CE at 100°C	RDX/TNT at 120°C	TORPEX 4A at 120°C	Others	SV Test at 80°C	Propellant and Stab Content	Trial Conditions	Increase in Stabiliser Consumption	
16	Aero Research Adhesive 2500 (MY 753/MY 905 50/50 pbw) 3 h at 180°C	CIBA (ARL) Ltd	3.9	C (0.01 ml)		C (3.47 ml)	Amatol (C) (1.82 ml) Pentolite (C) (2.76 ml)	C (1773 h)	SC 8.81 (Carbamite)	4 weeks 80°C Cured Resin	7% (C)	Plastic Prop RD2304 (C) (0.02 ml) Ammonium Picrate (C) (2.03 ml)
17	MY 753/HDNR X33/1152 100/30 pbw 6 h at 180°C	"	7.4	C (0.30 ml)	C (3.14 ml)	C (2.90 ml)	Amatol (C) (1.87 ml) Pentolite (C) (3.35 ml) RDX (C) (0.15 ml) TNT (C) (0.61 ml)	C (2118 h)	"	"	7% (C)	Gunpowder G20 (C)
18	AERODUX 185/HDNR HRP 150 100/20 pbw 24 h at room temp	"	8.3	C (1.22 ml)		C (0.88 ml)	RDX (C) (3.60 ml)					
19	AY 103/HY 956 100/18 pbw 3 h at 100°C	"	7.8	C (3.27 ml)	I (11.22 ml)		RDX (I) (12.47 ml)	C (1623 h)				
20	Araldite Adhesive 2000S MY 985/Aluminium/Mica/ Phthalic Anhydride 100/5/10/22 pbw 1½ h at 180°C	"	6.1	C (0.02 ml)	C (0.72 ml)	C (0.92 ml)	Amatol (C) (3.13 ml)	C (3224 h)	SC 8.81 (Carb) N 7.21 (Carb) NH 1.02 (DPA)	4 weeks 80°C Cured Resin " 3 weeks 80°C Cured Resin	17% (C) 4% (C) 0% (C)	Plastic Prop RD2307 (C) 0.79 ml) Gunpowder G20 (C) Compositions SR414, SR562, PN739 (C)
21	Araldite 985E C1/C3 1/3 pbw 1 h at 200°C	"		C (1.02 ml)	C (4.12 ml)			C (2230 h)	SC (8.81) Carb N (7.21) Carb	4 weeks 80°C Cured Resin	13% (C) 12% (C)	
22	ATI Hot Setting Type I Rod and Hardener (dicyandiamide) (1) Uncured	"		C (4.10 ml)	I (12 ml)	I (15 ml)		C (4435 h)				
	(2) 1½ h at 180°C		11.9	C (0.00 ml)	I (12 ml)	I (14 ml)	RDX (C) (1.28 ml) TNT (I) (9.74 ml) Amatol (C) (4.17 ml) Pentolite (C) (4.62 ml)	C (4000 h)	SC 8.81 (Carb) N 7.21 (Carb)	4 weeks 80°C Cured Resin "	9% (C) 10% (C)	Gunpowder G40 (C)

TABLE 8 (Contd)

No	Resin Ingredients and Cure Schedule	Manufacturer	pH Value (aqueous extract)	Compatibilities (C = Compatible; I = Incompatible)							Clearance with Pyrotechnics, Initiators and Plastic Propellants
				High Explosives (VS Results)				Colloidal Propellants			
									Stabiliser Tests		
				CE at 100°C	RDX/TNT at 120°C	TORPEX 4A at 120°C	Others	SV Test at 80°C	Propellant and Stab Content	Trial Conditions	Increase in Stabiliser Consumption	
23	AY 105/HY 953F 50/50 pbw	CIBA (ARL) Ltd		RDX/TNT at 100°C								
	(1) 24 h at 20°C		10.1	I (14.9 ml)	I (14.9 ml)							
	(2) 3 h at 60°C		8.6	I (8.6 ml)	I (8.80 ml)							
	(3) 20 m at 100°C		8.2	I (9.7 ml) (5 h duration of test)	I (13.1 ml) ($1\frac{1}{2}$ h duration of test) See Notes*							
24	EPIKOTE 828/VERSAMID 100 70/30 pbw 1 h at 150°C	Shell Chemicals Ltd		C (2.98 ml)	I (12.90 ml)							
25	EPIKOTE 828/VERSAMID 115 70/30 pbw 20 min at 150°C	"		C (1.36 ml)	I (11.66 ml)							
26	EPIKOTE 828/VERSAMID 125 70/30 pbw 10 min at 150°C	"		C (1.95 ml)	I (10.08 ml)							
27	EPIKOTE 828/HET ANHYDRIDE 100/117 pbw 24 h at 120°C	"	5.0	C (0.15 ml)	C (1.71 ml)	C (2.14 ml)	Amatol (C) (4.11 ml) Pentolite (C) (4.72 ml)	C (718 h)	SC 8.81 (Carbamite)	4 weeks 80°C Cured Resin	11% (C)	Plastic Prop RD2304 (C) (0.60 ml) Gunpowder G20 (C)
28	EPIKOTE 828/HDNR K61B 100/10.5 pbw 2 h at 180°C	"	6.2		I (11.79 ml)			C (3224 h)	SC 8.81 (Carb) N 7.21 (Carb) NH 1.02 (DPA)	4 weeks 80°C Cured Resin " 3 weeks 80°C Cured Resin	12% (C) 7% (C) 1% (C)	Plastic Prop RD2304 (C) (0.88 ml)
29	EPIKOTE 828/Piperidine 100/5 pbw 5 h at 100°C	"	8.6	C (1.45 ml)	I (14.44 ml)		Amatol (C) (15.32 ml) Pentolite (I) (7.21 ml)	C (3256 h)	SC 8.81 (Carbamite)	4 weeks 80°C Cured Resin	32% (I)	

*See Table 7

TABLE 8 (Contd)

No	Resin Ingredients and Cure Schedule	Manufacturer	pH Value (aqueous extract)	Compatibilities (C = Compatible; I = Incompatible)							Clearance with Pyrotechnics, Initiators and Plastic Propellants
				High Explosives (VS Results)				Colloidal Propellants			
									Stabiliser Tests		
				CE at 100°C	RDX/TNT at 120°C	TORPEX 4A at 120°C	Others	SV Test at 80°C	Propellant and Stab Content	Trial Conditions	Increase in Stabiliser Consumption	
30	EPIKOTE 828/BORESTER 8 100/2 pbw 24 h at room temp	Shell Chemicals Ltd	6.6	C (0.27 ml)	C (1.10 ml)	C (0.94 ml)	Pentolite (C) (1.90 ml) PETN (C) (0.32 ml) Amatol (I) (11.53 ml)	C (1288 h)	SC 8.81 (Carb) N 7.21 (Carb) NH 1.02 (DPA)	4 weeks 80°C Cured Resin " 3 weeks 80°C Cured Resin	11% (C) 11% (C) 0% (C)	Plastic Prop RD2304 (C) (0.08 ml) Gunpowder G20 (C)
31	EPIKOTE 828/THIOKOL LP3/K61B 100/66/10 pbw Cured at room temp	"	6.8	C (2.20 ml)			RDX (I) (6.10 ml) TNT (I) (6.47 ml)					
32	EPON 1001/VERSAMID 100 70/30 pbw 1 h at 150°C			C (1.13 ml)	I (9.97 ml)							
33	EPON 1001/VERSAMID 115 70/30 pbw 20 min at 150°C	"	7.2	C (1.14 ml)	I (10.13 ml)			C (2544 h)	SC 8.81 Carbamite	4 weeks 80°C Cured Resin	10% (C)	
34	EPIKOTE 1007/HDNR K61A 100/10.5 pbw 16 h at 50°C	"		C (1.14 ml)	I (11.79 ml)	I (12.82 ml)	Amatol (I) (15.46 ml)	C (3120 h)				
35	EPIKOTE 1007/HDNR K61B 100/10.5 pbw 16 h at 50°C	"		C (1.11 ml)	I (11.14 ml)	I (12.77 ml)	Amatol (I) (12.17 ml) PETN (I) (11.89 ml)	C (3217 h)				
36	EPON RESIN VI/CURING AGENT "A" 100/10 pbw 1½ h at 100°C	"										Plastic Prop RD2304 (C) (0.81 ml)
37	EPIKOTE 871/NMA/BDMA 100/45/2 pbw 1 h at 100°C plus 15 h at 150°C	"	4.0		C (1.87 ml)		RDX (C) (2.35 ml)					

TABLE 8 (Contd)

No	Resin Ingredients and Cure Schedule	Manufacturer	pH Value (aqueous extract)	Compatibilities (C = Compatible; I = Incompatible)							Clearance with Pyrotechnics, Initiators and Plastic Propellants
				High Explosives (VS Results)				Colloidal Propellants			
									Stabiliser Tests		
				CE at 100°C	RDX/TNT at 120°C	TORPEX 4A at 120°C	Others	SV Test at 80°C	Propellant and Stab Content	Trial Conditions	Increase in Stabiliser Consumption	
38	EPIKOTE 828/TET 3 days at room temp	Shell Chemicals Ltd	6.3	C (2.48 ml)		I (11.42 ml)	Amatol (I) 7.47 ml) PETN (C) (2.76 ml)	C (2944 h)	SC (8.81) CARB N (7.21) CARB NH (1.02) DPA	4 weeks 80°C Cured Resin 3 weeks 80°C	20% (I) 20% (I) 0% (C)	
39	EPOPHEN EL5/HDNR EHL-7Z 1/1 pbw 24 h at room temp	Borden Chemical Co Ltd	8.3	C (1.20 ml)	I (9.47 ml)			C (1617 h)				Gunpowder SF (C)
40	EPOPHEN EL5/HDNR EHM 2 1/1 pbw 24 h at room temp	"	7.0		C (3.43 ml)							
41	EPOPHEN EL5/HDNR EHR 1 100/80 pbw 24 h at room temp	"	7.2	I (12.96 ml)	I (11.68 ml)			C (2116 h)	N 7.21 Carbamite	4 weeks 80°C Cured Resin	10% (C)	Plastic Prop RD2304 (C) (0.12 ml) Lead Styphnate (C) Lead Dinitroresorcinate (C) Tetrazene (C)
42	EPOPHEN EL5/HDNR EHM 4 100/75 pbw 24 h at room temp	"	7.9	I (11.86 ml)	I (12.14 ml)	I (11.94 ml)						Plastic Prop RD2304 (C) (0.12 ml) Lead Styphnate (C) Lead Dinitroresorcinate (C) Tetrazene (C)
43	EPOPHEN ET2A/HDNR EHR 1 100/80 pbw 24 h at room temp	"	6.6	I (12.38 ml)	I (12.64 ml)		Amatol (I) (11.77 ml) Pentolite (I) (13.72 ml)	C (2107 h)				Plastic Prop RD2304 (C) (0.86 ml) Gunpowder G20 (C) RD1652 Composition (C) VH_2 Composition (C)
44	R18774/1/HDNR Q 18988 4/1 pbw 2 h at 100°C	Bakelite Ltd	8.9	I (5.65 ml)			RDX (I) (5.00 ml) TNT (I) (10.97 ml)					

TABLE 8 (Contd)

No	Resin Ingredients and Cure Schedule	Manufacturer	pH Value (aqueous extract)	Compatibilities (C = Compatible; I = Incompatible)							Clearance with Pyrotechnics, Initiators and Plastic Propellants
				High Explosives (VS Results)				Colloidal Propellants			
									Stabiliser Tests		
				CE at 100°C	RDX/TNT at 120°C	TORPEX 4A at 120°C	Others	SV Test at 80°C	Propellant and Stab Content	Trial Conditions	Increase in Stabiliser Consumption	
45	R18774/1/HDNR Q 19027 2/1 pbw 1 h at 100°C	Bakelite Ltd	10.2	I (7.66 ml)			RDX (I) (15.22 ml) TNT (I) (10.93 ml)					
46	R18774/1/VERSAMID 125 40/60 pbw 24 h at room temp	"		C (2.66 ml)			RDX (I) (10.03 ml)					
47	R18774/1/VERSAMID 140 40/60 pbw 36 h at room temp	"	8.8	I (12.23 ml)	I (16.72 ml)		RDX (I) (15.10 ml) TNT (I) (15.0 ml)					
48	R18774/1/VERSAMID 140 70/30 pbw 3 days at room temp	"	8.0	I (5.76 ml)		I (8.56 ml)	Amatol (I) (12 ml) Pentolite (I) (11 ml)					Lead Styphnate (C)

S No 71/GC/72

UNCLASSIFIED

Technical Report No 110
Explosives Research and Development Establishment
THE COMPATIBILITY OF EPOXY RESINS WITH EXPLOSIVES
Blay N J, Pembridge E F
July 1972
26 pp, 8 tabs, no figs

The explosives compatibility properties of a number of commercial epoxy resin materials are discussed and reported and an account is given of hazard appraisal and compatibility tests of several reactive hardener components and of resin-hardener mixtures in the uncured condition.

UNCLASSIFIED

UNCLASSIFIED

Technical Report No 110
Explosives Research and Development Establishment
THE COMPATIBILITY OF EPOXY RESINS WITH EXPLOSIVES
Blay N J, Pembridge E F
July 1972
26 pp, 8 tabs, no figs

The explosives compatibility properties of a number of commercial epoxy resin materials are discussed and reported and an account is given of hazard appraisal and compatibility tests of several reactive hardener components and of resin-hardener mixtures in the uncured condition.

UNCLASSIFIED

UNCLASSIFIED

Technical Report No 110
Explosives Research and Development Establishment
THE COMPATIBILITY OF EPOXY RESINS WITH EXPLOSIVES
Blay N J, Pembridge E F
July 1972
26 pp, 8 tabs, no figs

The explosives compatibility properties of a number of commercial epoxy resin materials are discussed and reported and an account is given of hazard appraisal and compatibility tests of several reactive hardener components and of resin-hardener mixtures in the uncured condition.

UNCLASSIFIED

UNCLASSIFIED

Technical Report No 110
Explosives Research and Development Establishment
THE COMPATIBILITY OF EPOXY RESINS WITH EXPLOSIVES
Blay N J, Pembridge E F
July 1972
26 pp, 8 tabs, no figs

The explosives compatibility properties of a number of commercial epoxy resin materials are discussed and reported and an account is given of hazard appraisal and compatibility tests of several reactive hardener components and of resin-hardener mixtures in the uncured condition.

UNCLASSIFIED

[dstl] Porton Down
Salisbury
Wilts
SP4 0JQ

Defense Technical Information Center (DTIC)
8725 John J. Kingman Road, Suit 0944
Fort Belvoir, VA 22060-6218
U.S.A.

AD#: AD907380

Date of Search: 8 December 2008

Record Summary: AVIA 37/1430
Title: The compatibility of epoxy resins with explosives
Availability Open Document, Open Description, Normal Closure before FOI Act: 30 years
Former reference (Department) ERDE TR 110
Held by The National Archives, Kew

This document is now available at the National Archives, Kew, Surrey, United Kingdom.

DTIC has checked the National Archives Catalogue website (http://www.nationalarchives.gov.uk) and found the document is available and releasable to the public.

Access to UK public records is governed by statute, namely the Public Records Act, 1958, and the Public Records Act, 1967.
The document has been released under the 30 year rule.
(The vast majority of records selected for permanent preservation are made available to the public when they are 30 years old. This is commonly referred to as the 30 year rule and was established by the Public Records Act of 1967).

This document may be treated as UNLIMITED.